R&D considerations for Large Water Detector project for DUSEL

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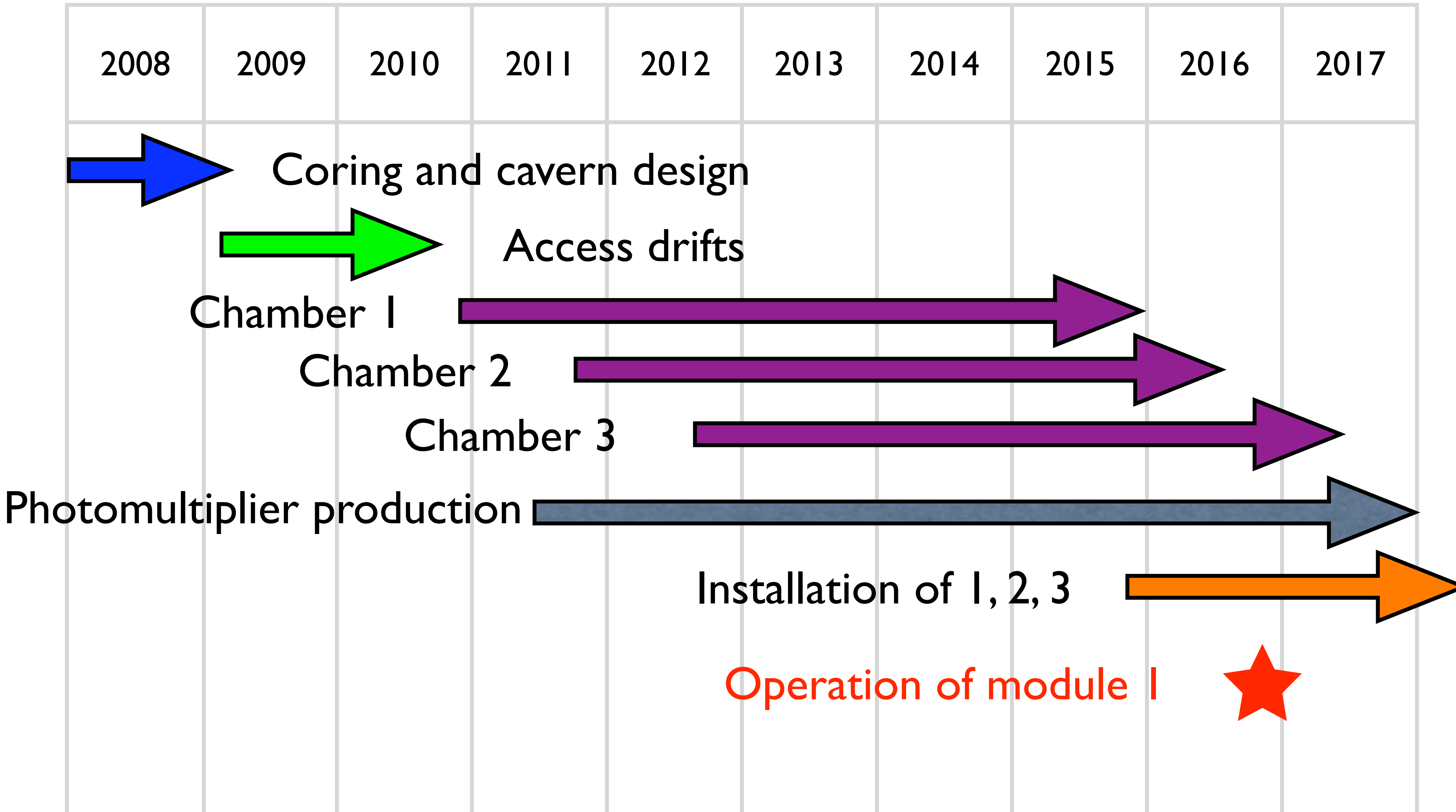
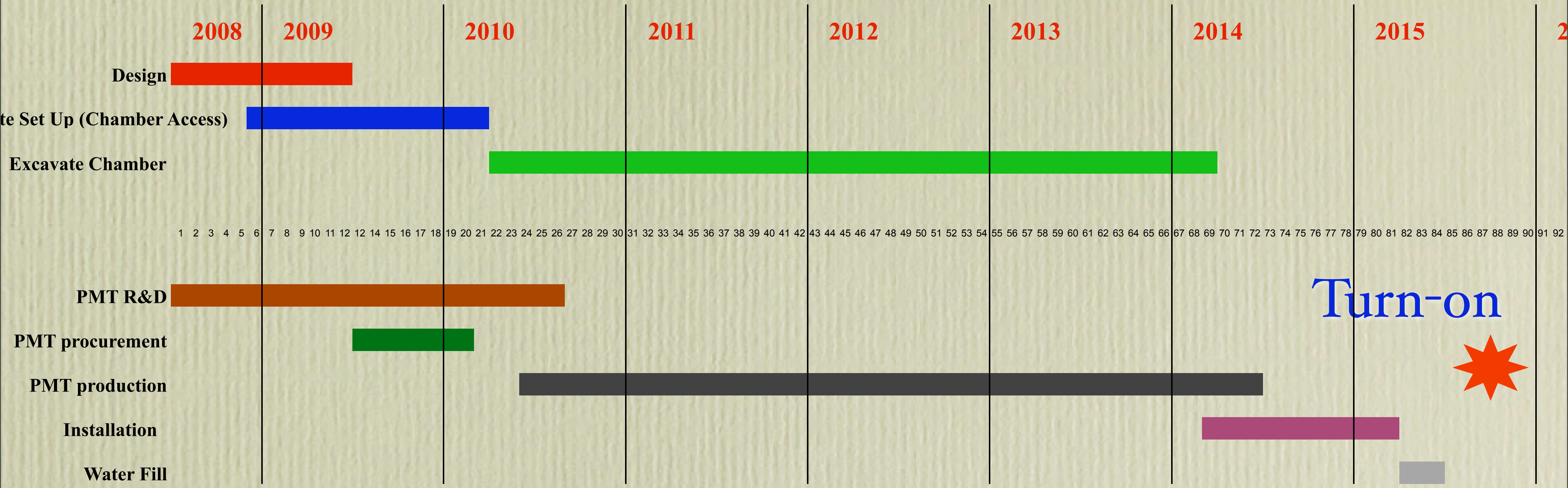
Lead

Items for this talk

- Comments on software (Mainly from Brett Viren)
- Photo-multiplier R&D at BNL


2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
Coring and cavern design
Access drifts
Chamber 1
Chamber 2
Chamber 3
Photomultiplier production
Installation of 1, 2, 3
Operation of module 1

Technically limited schedule for a single 100 kT fiducial detector

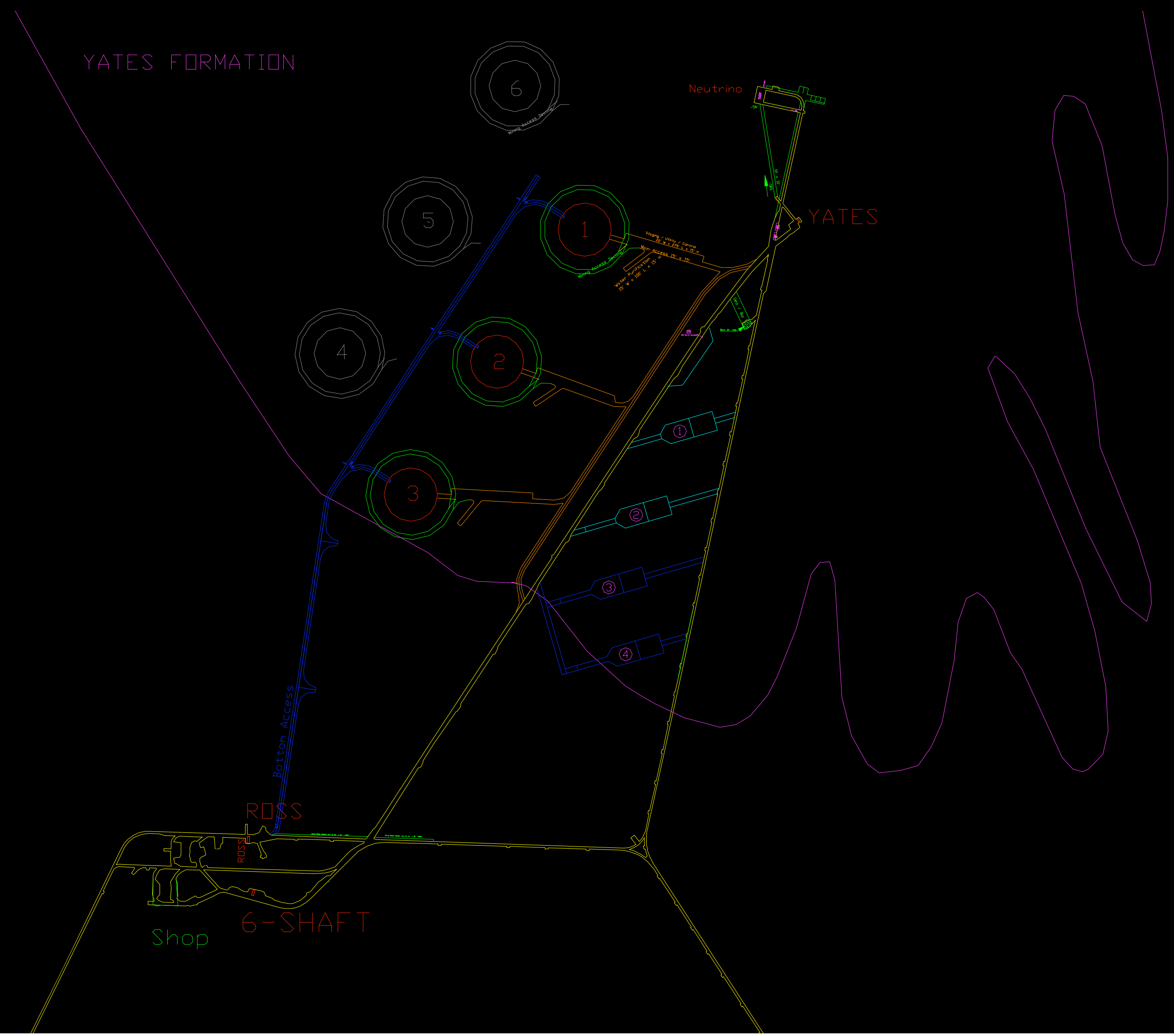


Comments: Phototube production is slowed down to match construction of 1 module only.
Schedule is strictly technical. Does not account for review process. See KTLesko talk
PMT testing facility, water system procurement and installation, and other items are not shown here.

- Tube production is slowed to match excavation. Tube production is NOT the limiting factor.
- For simplicity, water system, PMT testing, electronics, etc. are not shown.
- For 300 kT the time need not be tripled.

Megaton Modular Multi-Purpose Neutrino Detector

✓ **Modular Configuration**



Software (BViren)

- Perhaps the most important and complex technical system for the water Cherenkov detector. Includes simulation, calibration, reconstruction.
- I suggest that there be a subgroup immediately working on this.

Meta requirement: architecture

a) No organization - let it evolve organically
  * Historically the "Physicists Way"
  * Fastest short term results
  * Individual star programmers, confused users
  * Progressively harder to maintain
  * Not suited for easy collaboration and code sharing
  * Reinvents wheels

b) Select existing or develop new software framework
  * Requires commitment from all developers.
  * Need champion experts (or those that can become expert)
  * Significant up-front development/learning costs
  * Long term maintenance is relatively easy
  * Easy for non-experts to contribute, extend, modify
  * Steal those wheels that work, invent where needed
  * Likely candidate: Gaudi (general) + GiGa (Geant4sim) frameworks

   ** Expertise in HEP comunity (LHC exps, Minerva, Daya Bay)
   ** Code available, CERN support
   ** Core developers open to helping other exps.

For now there is time to start with either (a) or (b).
Long term, (b) is prefered.

Simulation

Detector simulation requirements

* Flexibility - easily simulate different designs:

  ** geometry:
  *** grossly different designs (w/ or w/out OD)
  *** different parametrized values (50m diameter tank vs. 53m)
  *** discrete differences (10% vs. 25% vs. 40% PMT coverage)

  ** optical parameters
  *** attenuation length
  *** material reflectivities

  ** PMTs
  *** PMT to PMT QE differences
  *** Nonuniformities
  *** Earth's B-field

* Acuracy - must correctly simulate all salient features and not rely on scaling/reweighting assumptions.

Electronics simulation requirements.

* Initially enough to have "dummy" hit->adc/tdc conversion
* Able to swap in different single-PE responses
* Support alternative readouts: eg. flash-ADC.

Reconstruction

Reconstruction requirements:

* Adaptability - must work at a basic level with each different designs.

* Optimization - different designs may have different "local maxima" of performance. Reconstruction needs to be able to find these to prove the design's worth.

* Modularity - decouple orthogonal reconstruction algorithms. Allow competing algorithms to run side-by-side. Allow iterative running of reconstruction modules.

Visualization requirements:

* Geometry validation - need ways to confirm detector geometry is as expected.

* Reconstruction - event displays and intermediate data visualization needed to understand and develop reco. code.

PMT R&D

- Issues are: making 150000 tubes in 6 years time, their efficiency, and their pressure performance.
- If PMTs can stand higher pressure, the cavern can be taller => more fiducial volume.
- Have had meetings with Photonis and Hamamatsu: no barrier to PMT production except money.

PMT considerations

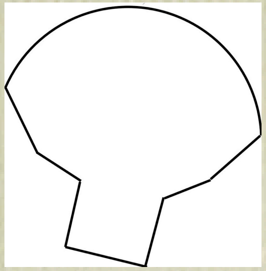
	10 inch R7081	20 inch R3600
Number (25% cov)	~50000	~14000
QE	25%	20%
CE	~80%	~70%
rise time	4 ns	10 ns
Tube length	30 cm	68 cm
Weight	1150 gm	8000 gm
Vol.	~5 lt	~50 lt
pressure rating	0.7Mpa	0.6Mpa
∢ coverage/pmt	0.6 deg	1.1 deg
∢ granularity	1.0 deg	2.1 deg

Tube production

Glass

Stamped metal and wire parts

First assembly
vacuum deposition of metal platings
Graded seal



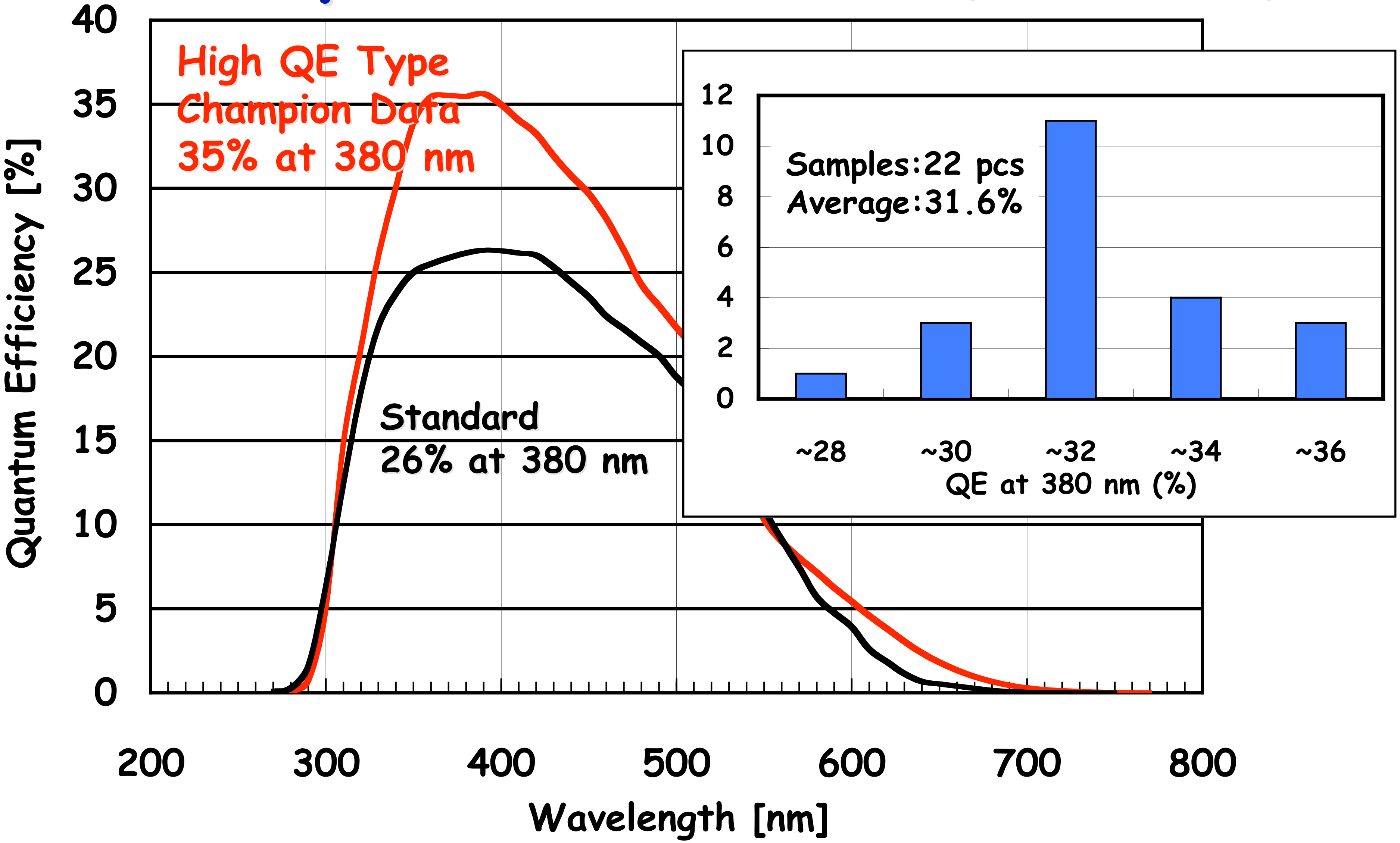
Final vacuum
Cathode deposition

Final assembly of 10 inch tubes needs lab space of 30’x30’; six stations with 6 pmts/station; 1 full day => 36tubes/day = icecube production.
tripling this rate is not difficult

HPK and Photonis are NOT concerned about their ability to manufacture at this rate

HAMAMATSU

Example data R7081 (10 inch)



Goal of development is 43%

M.Diwan

Office of Science U.S. DEPARTMENT OF ENERGY

BROOKHAVEN NATIONAL LABORATORY

SPECIFICATIONS

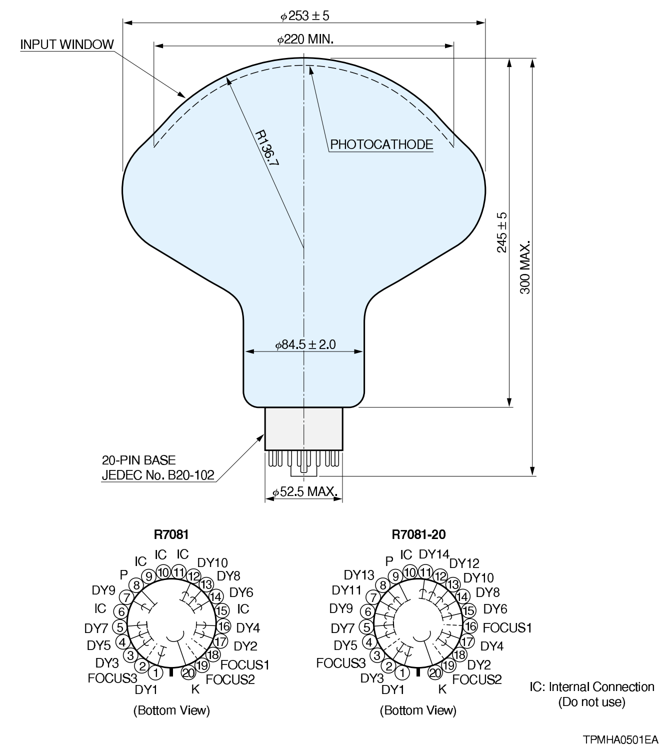
Type No.	Cathode Sensitivity: Luminous (2856 K) Min. (µA/lm)	Luminous (2856 K) Typ. (µA/lm)	Radiant at 420 nm Typ. (mA/W)	Blue Sensitivity Index (CS 5-58) Min.	Blue Sensitivity Index (CS 5-58) Typ.	Quantum Efficiency at 390 nm Typ. (%)	Anode Sensitivity: Luminous (2856 K) Typ. (A/lm)	Radiant at 420 nm Typ. (A/W)	Gain Typ.	Applied Voltage for Typical Gain Typ. (V)
R5912	40	70	72	6.0	9.0	22	700	7.2×10^5	1.0×10^7	1500
R5912-02	40	70	72	6.0	9.0	22	70 000	7.2×10^7	1.0×10^9	1700
R7081	40	80	80	6.0	10.0	25	800	8.0×10^5	1.0×10^7	1500
R7081-20	40	80	80	6.0	10.0	25	80 000	8.0×10^7	1.0×10^9	1700
R8055	35	60	65	5.5	8.0	20	600	6.5×10^5	1.0×10^7	1500
R3600-02	35	60	65	5.5	8.0	20	600	6.5×10^5	1.0×10^7	2000
R7250	35	60	65	5.5	8.0	20	600	6.5×10^5	1.0×10^7	2000

NOTE: Anode characteristics are measured with the voltage distribution ratio shown below.
(   ): Measured with the special voltage distribution ratio (Tapered Divider) shown below.

Maximum Ratings

Type No.	Supply Voltage: Anode to Cathode (V)	Supply Voltage: Anode to Last Dynode (V)	Average Anode Current (mA)	Operating Ambient Temperature (°C)	Storage Temperature (°C)	Pressure (MPa)	Direct Interelectrode Capacitances: Anode to Last Dynode (pF)	Anode to All Other Dynodes (pF)
R5912	2000	300	0.1	-30 to +50	-30 to +50	0.7	approx. 3	approx. 7
R5912-02	2000	300	0.1	-30 to +50	-30 to +50	0.7	approx. 3	approx. 7
R7081	2000	300	0.1	-30 to +50	-30 to +50	0.7	approx. 3	approx. 7
R7081-20	2000	300	0.1	-30 to +50	-30 to +50	0.7	approx. 3	approx. 7
R8055	2500	300	0.1	-30 to +50	-30 to +50	0.15	approx. 10	approx. 20
R3600-02	2500	300	0.1	-30 to +50	-30 to +50	0.6	approx. 36	approx. 40
R7250	2500	300	0.1	-30 to +50	-30 to +50	0.6	approx. 10	approx. 15

●R7081, R7081-20

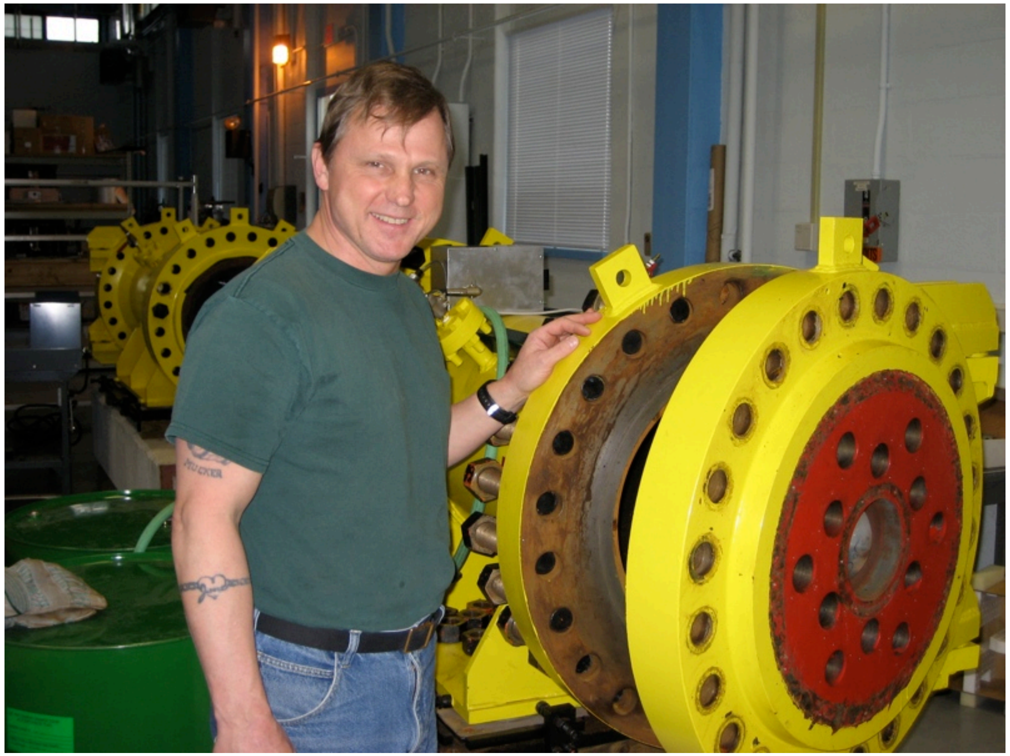


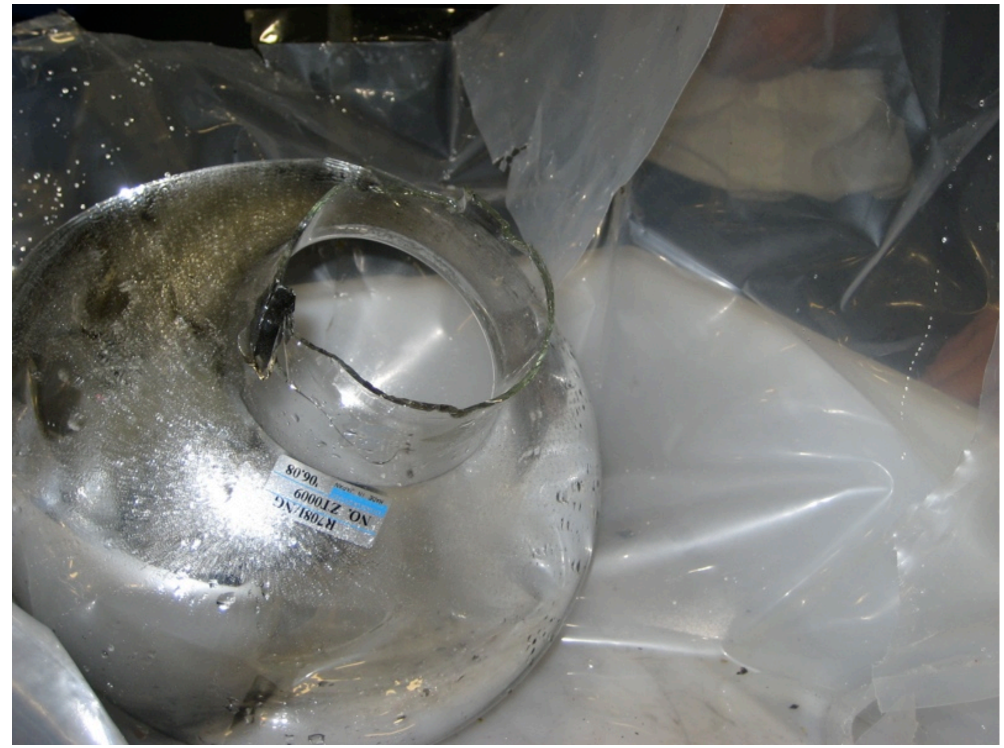
We are focussed on the R7081 tube

It is more efficient than the R3600.

25% *R7081 => 35% *R3600

Pressure testing





Have 32 phototubes from Hamamatsu. Pressure vessel from BNL. Evolving testing protocol.

Hamamatsu rating is ~7atm. Tested this tube until it broke at 148 psi (~10atm)

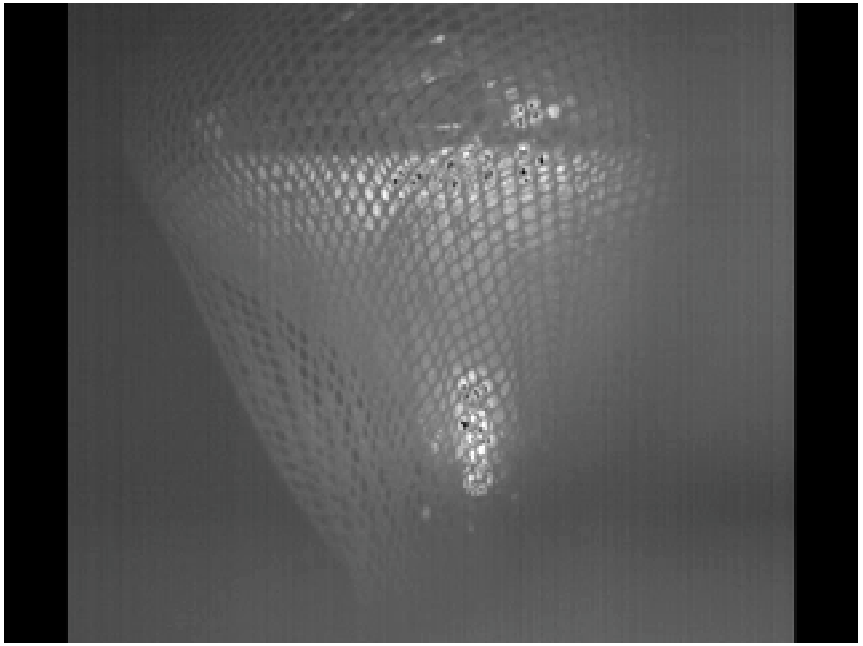
Data so far

PMT	size	Break Press
R7081/ng 1	10inch	148 psi
XP1807 1	12 inch	92 psi
xp18060 1	8 inch	35 psi
R7081 2	10 inch	cycled 132psi
R7081 3	10 inch	cycled 132 psi
R7081 4	10 inch	cycled 132 psi
R7081/lowr1	10 inch	205 psi
R7081/lowr 2	10 inch	218 psi

Hamamatsu tested 3 R7081 upto ~10 atm.
One broke at 10 atm,
On each tube, there is data on glass thickness, pressure pulse duration, etc.

What kind of information ?

- Pressure at implosion
- Implosion process. (fast motion movie), photos
- Pressure pulse



↔ 2.5 ms

Breakage at pins

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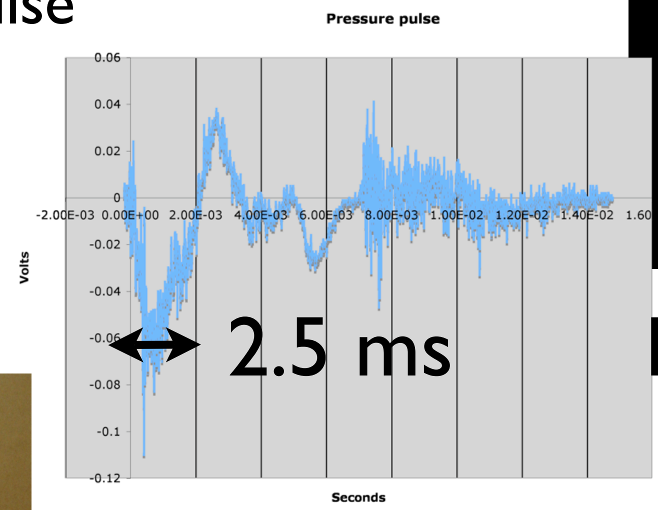

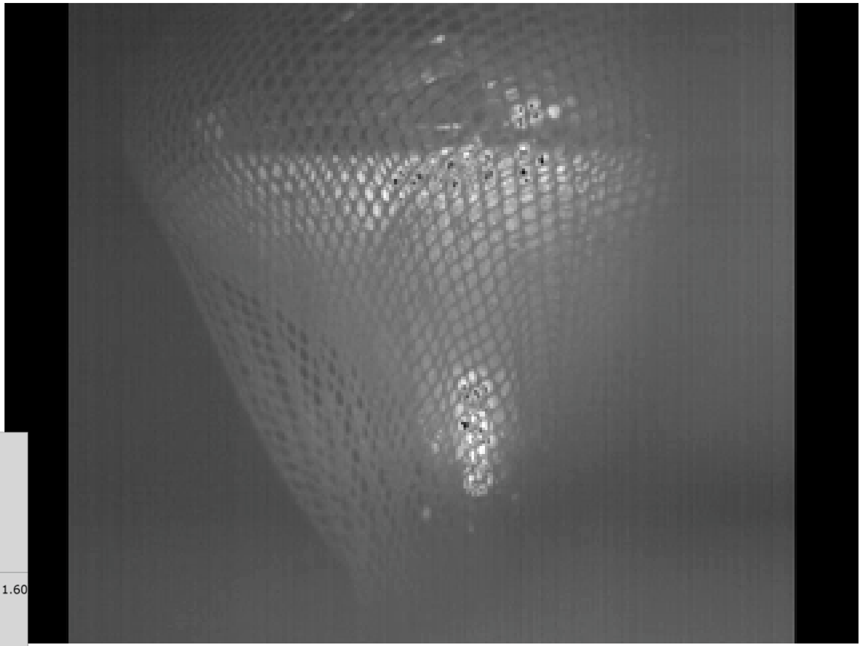

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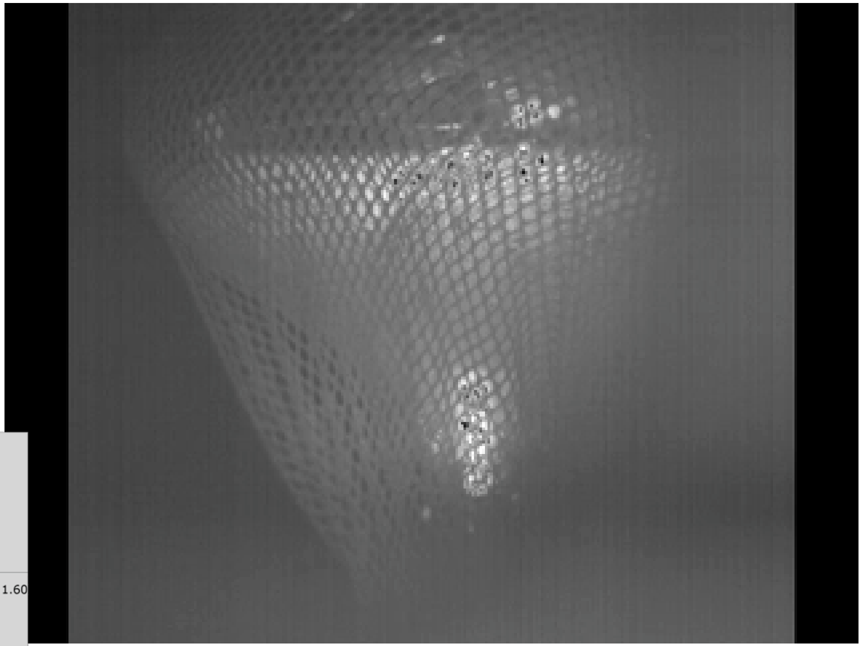

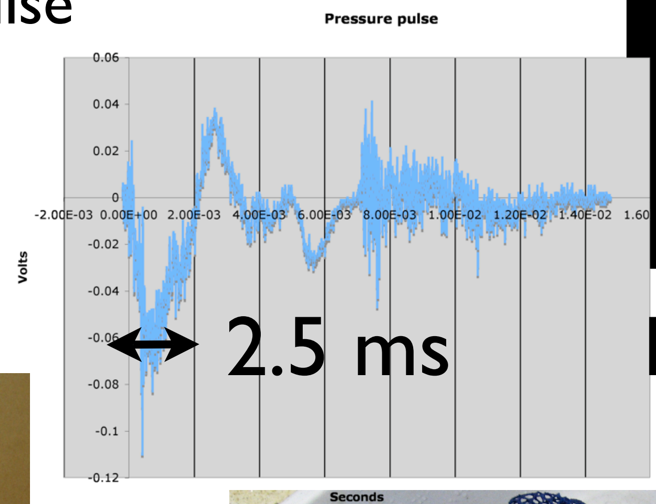

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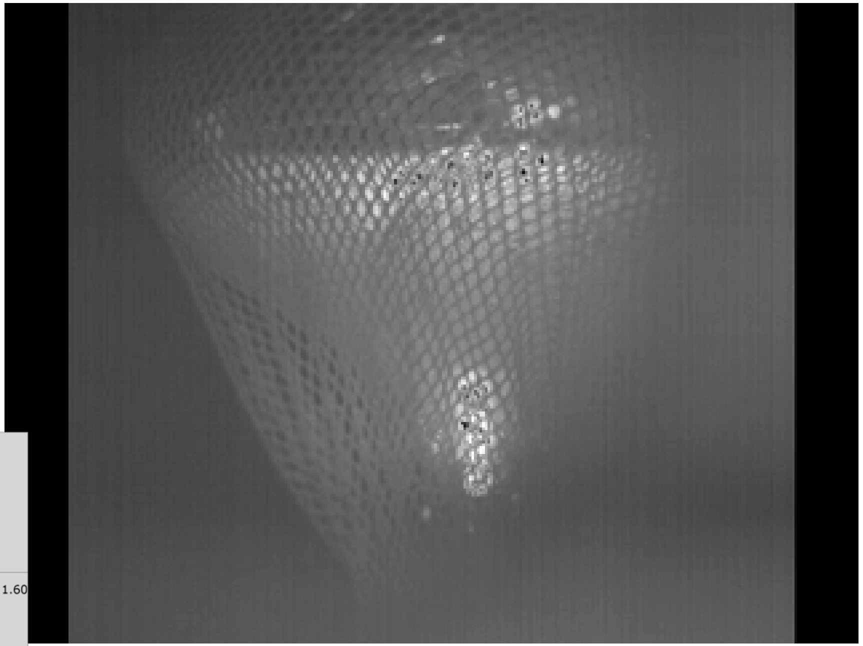

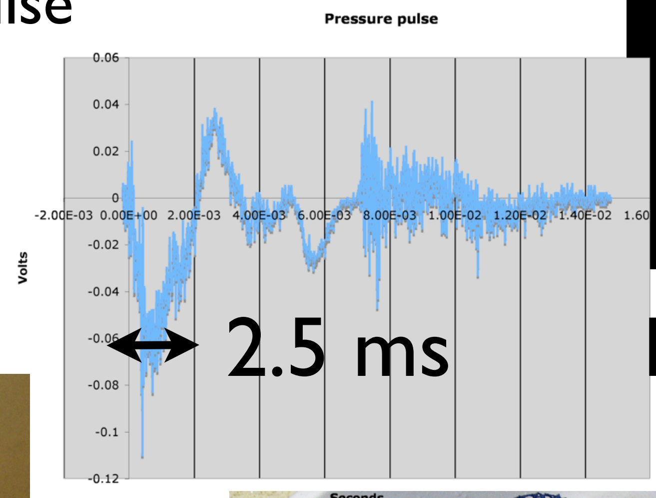

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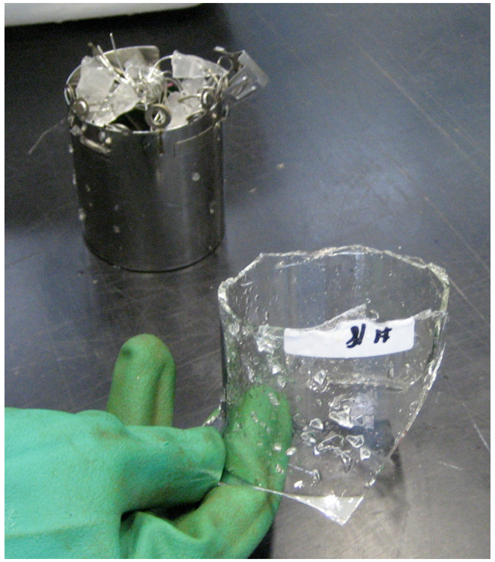

PMT cost in current plan

	Cost for one
28 cm dia PMT	$933
Installation/PM	$175
Electronics/PM	$127
Cable/PM	$86
Total per PMT	$1317

50000 PMTs per 100 kT tank => 25% coverage
Sanity checks: Auger PMT cost $629/each for 5000 units with 9 inch diameter. Base cost additional $175. Other costs have basis with SNO actual costs with adjustments for differences.

Summary cost ($FY07) for 300kT

Cavity construction (30% contingency)	$78.9M
PMT+electronics	$171.3M
Installation+testing	$35.7M
R&D, Water, DAQ, etc.	$8.2M
Contingency(non-civil)	$50.8M
Total	$344.9M

Summary

- Software work should be started immediately.
- PMT R&D is in progress. There is considerable development in place at BNL, especially on pressure testing.
- Helpful to have more people involved and other setups.